Is the Hydrological Cycle Accelerating?

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2 authors:

Atsumu Ohmura
ETH Zurich

Martin Wild
ETH Zurich

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penetration of seawater. Propagation of cracks and fractures necessary for fluid ingress would be inhibited by the large increase in rock volume accompanying serpentinization (*8*). The hypothesis that surface water is drawn to such depths by dilatancy (increase in pore volume) arising from seismic pumping associated with deep earthquakes (*2*) is difficult to reconcile with hydraulics.

Seismic tomography offers a potential way to image serpentinite remotely in subducted slabs. The ratio of *P* and *S* seismic wave velocities is directly proportional to Poisson's ratio (the ratio of longitudinal to transverse strain in a uniaxially stressed material). Serpentinite has an unusually high Poisson's ratio, providing a means to detect it at depth. It has been imaged in the mantle wedge overlying subduction zones (*9*). Serpentinite exposed in forearcs (*10*) (see the figure) provides direct evidence of its existence in mantle wedges.

However, the critical question here is whether serpentinite exists in subducted plates. Computing Poisson's ratio from seismic tomography, Omori *et al*. (*3*) suggest that substantial quantities of serpentinite exist to depths of ~50 km below the top of the subducted plate in northeast Japan. If this interpretation is valid, we require a credible mechanism for hydrating mantle peridotite to such depths.

Further evidence for or against serpentinite in subducted plates should come from detailed seismic tomography of areas with known serpentinite at depth (*10*). The serpentinite enigma is further compounded by uncertainties regarding the pressure-temperature conditions of serpentinite dehydration and the thermal structure of subduction zones (*3*).

The fluid required for mantle wedge serpentinization could derive from sources other than serpentinite in the subducted oceanic crust. Other sources might be metamorphic devolatilization of subducted marine sediments (*11*) and hydrothermally altered oceanic basalts (*12*). Dehydration of the mantle wedge serpentinites could then supply fluids to arc magmas (*13*). Comparison of the trace element and isotopic compositions of serpentinites exposed in forearcs (*10*) with those of the Mid-Atlantic Ridge and ophiolites (*14*) may help to determine whether arc magma fluids derive from mantle wedge or oceanic plate serpentinites.

In the distant future, a change in global dynamics may cause the Atlantic plate to undergo subduction. I postulate that the large amount of water released by dehydration of the subducted Atlantic oceanic serpentinites will then result in a significant quantity of arc volcanism and a lot of earthquake activity.

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PERSPECTIVES: CLIMATE CHANGE

Is the Hydrological Cycle Accelerating?

Atsumu Ohmura* and Martin Wild

Early studies of instrumentally detected climate change (*1–3*) mostly concentrated on the history of measured air temperature. More recent research has investigated the variability of other climatic factors such as irradiance (*4, 5*), water vapor (*6*), wind speed (*6*), and precipitation (*7*). In interpreting these data sets, researchers were conscious of the recent global warming and the expected consequences of the enhanced greenhouse effect.

One of these expectations was that evaporation would increase under a warmer climate. But in 1995, Peterson *et al*. reported a decrease in pan evaporation between 1950 and 1990, based on data from the United States and the former Soviet Union (*8*). The authors used data from a network of pan evaporimeters. These simple instruments consist of a water-filled pan, a device to measure the water needed to return the surface to a predetermined level, and a rain gauge (see the figure). They were first used in the 19th century, but only since 1951 have homogeneous data been available.

Peterson *et al*. (*8*) did not distinguish between pan evaporation and terrestrial and potential evaporation (*9*). They found the decreasing pan evaporation (and hence terrestrial and potential evaporation) to be in phase with the decreasing diurnal temperature range (daily maximum minus minimum temperature), which they related to increasing cloud cover. They thus concluded that evaporation had decreased in a warming climate.

In contrast, Brutsaert and Parlange (*10*) regarded the pan evaporation as fundamentally different from the terrestrial evaporation. They argued that the decreasing pan evaporation is a signal of increasing terrestrial evaporation, because the latter will cast moist air over a water-filled pan. The decreasing pan evaporation would then be an indication of an increase

Installations of the water evaporation pan. (**Left**) A Canadian Class-A pan installed at the northernmost point on Earth where evaporation pans were used (79°25′N, 90°45′W). The pan is separated from the ground with a wood plank to avoid local effects from the ground. (**Right**) A Chinese pan at Hongwuyve, Tenshan Mountains. The pan is buried in an effort to minimize the effect of the exposed side wall.

CREDIT: ATSUMU OHMURA

The authors are at the Institute for Atmospheric and Climate Science, ETH Zürich, 8057 Zürich, Switzerland.

*Affiliated with the Institute of Low Temperature Science, Hokkaido University, Sapporo, Japan. E-mail: ohmura@geo.umnw.ethz.ch

MEAN HEMISPHERIC EVAPORATION AND AIR TEMPERATURE FOR PRESENT-DAY CLIMATE

January	Northern Hemisphere (winter hemisphere)	Southern Hemisphere (summer hemisphere)
Evaporation (mm month^{-1})	91, 92[1]	77, 84
Temperature (°C)	8.5, 7.3	16.6, 16.5

July	Northern Hemisphere (summer hemisphere)	Southern Hemisphere (winter hemisphere)
Evaporation (mm month^{-1})	74, 87	102, 111
Temperature (°C)	22.0, 21.5	11.6, 11.0

[1]Red numbers (left), simulated with the ECHAM4 GCM; blue numbers (right), results from ERA15.

in terrestrial evaporation.

On page 1410 of this issue, Roderick and Farquhar offer a new explanation for the decreasing pan evaporation (*11*). They relate the downward pan evaporation trend to the decreasing solar radiation globally observed between 1957–1958 and 1990. The work is based on the concept of energy balance and is a valuable and interesting contribution to the present controversy.

The subject of evaporation changes is, however, far from settled with the present report. For instance, Xu has reported increasing pan evaporation over a large area in Asia (*12*). Further, it is not firmly established that global evaporation must increase under an enhanced greenhouse climate. When CO_2 was doubled in a simulation with the ECHAM3 general circulation model (GCM), a slight decrease in global evaporation was observed (*13*). A similar simulation with the GCM of the Meteorological Research Institute, Tsukuba, also showed a small decrease in global evaporation after doubling CO_2 (*14*).

Ultimately, what is important is the trend in actual evaporation. Pan evaporation matters insofar as it can offer a useful clue to the direction of the change in actual evaporation. Several issues remain to be resolved before we can fully understand the trend in global evaporation in our changing climate.

First, the direction of the evaporation trend is not determined by temperature alone. That a warmer atmosphere does not necessarily produce more evaporation can be seen in the fact that hemispheric evaporation is much more substantial in winter than in summer under the present climate. This fact was already established in 1963 (*15*) but passed largely unnoticed. A recent simulation of the present climate with the ECHAM4 GCM also clearly shows that a hemisphere evaporates more in winter than in summer. This result is supported by the European Re-Analysis (ERA) (*16*) by the European Centre for Medium-Range Weather Forecasts (ECMWF) (see the table).

Second, the evaporation trends from land and from the ocean must be studied separately. Under certain conditions they differ tremendously, especially when land evaporation is from drying soil surfaces. Ocean evaporation, on the other hand, depends heavily on nonatmospheric processes such as the ocean heat flux.

Third, the diurnal temperature range must be separated into two components: one due to the 24-hour periodicity and the other due to the non–24-hour variation. The former represents the effect of the diurnal cycle in radiation; the latter indicates the strength in advection. This treatment makes it possible to determine to what extent the trend in evaporation is due to changes in radiation fields or in the strength of circulation.

Finally, analyses of the evaporation and solar radiation of the last 10 years are urgently needed, because the increasing trend of global cloudiness reversed around 1990 (*17*). This type of study will clearly indicate whether the reported decrease is a segment of a longer trend caused by the human-made greenhouse effect or a short-term variation due to solar radiation.

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16. The ERA combines computed values and observed meteorological data. It reconstructs the three-dimensional atmosphere by combining the GCM-based calculation for weather forecasts and the subsequent observation of the same values. Satellite data are added for substantiating the atmosphere. This type of data set is called the "Analysis." The Re-analysis is the most comprehensive data set for climate research at present. It is made available to member countries of ECMWF for research purposes.
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PERSPECTIVES: CANCER

DNA Damage, Deamidation, and Death

Chi Li and Craig B. Thompson

A major challenge in cancer therapy is the identification of drugs that kill tumor cells while preserving normal cells. Some DNA-damaging agents are effective antineoplastic drugs because they damage malignant tissues more than normal tissues (*1*). In vitro, tumor cell death in response to DNA-damaging agents appears to result from the induction of apoptosis (programmed cell death). Paradoxically, many, if not all, human cancer cells display resistance to apoptosis (*2*). Among the major apoptotic regulators of the cell are proteins of the Bcl-2 family, some of which are antiapoptotic (such as Bcl-2 and Bcl-x_L) and others proapoptotic (such as Bax and Bak). Cells from many tumor types have an increased ratio of antiapoptotic to proapoptotic proteins, which enables them to resist stimuli that would normally induce apoptosis (*3*). These observations have made it difficult to reconcile the clinical effectiveness of anticancer agents that damage DNA and induce apoptosis with the apparent increase in apoptotic resistance of tumor cells.

A recent study in *Cell* by Deverman and

The authors are in the Department of Cancer Biology, Abramson Family Cancer Research Institute, University of Pennsylvania, Philadelphia, PA 19104, USA. E-mail: drt@mail.med.upenn.edu